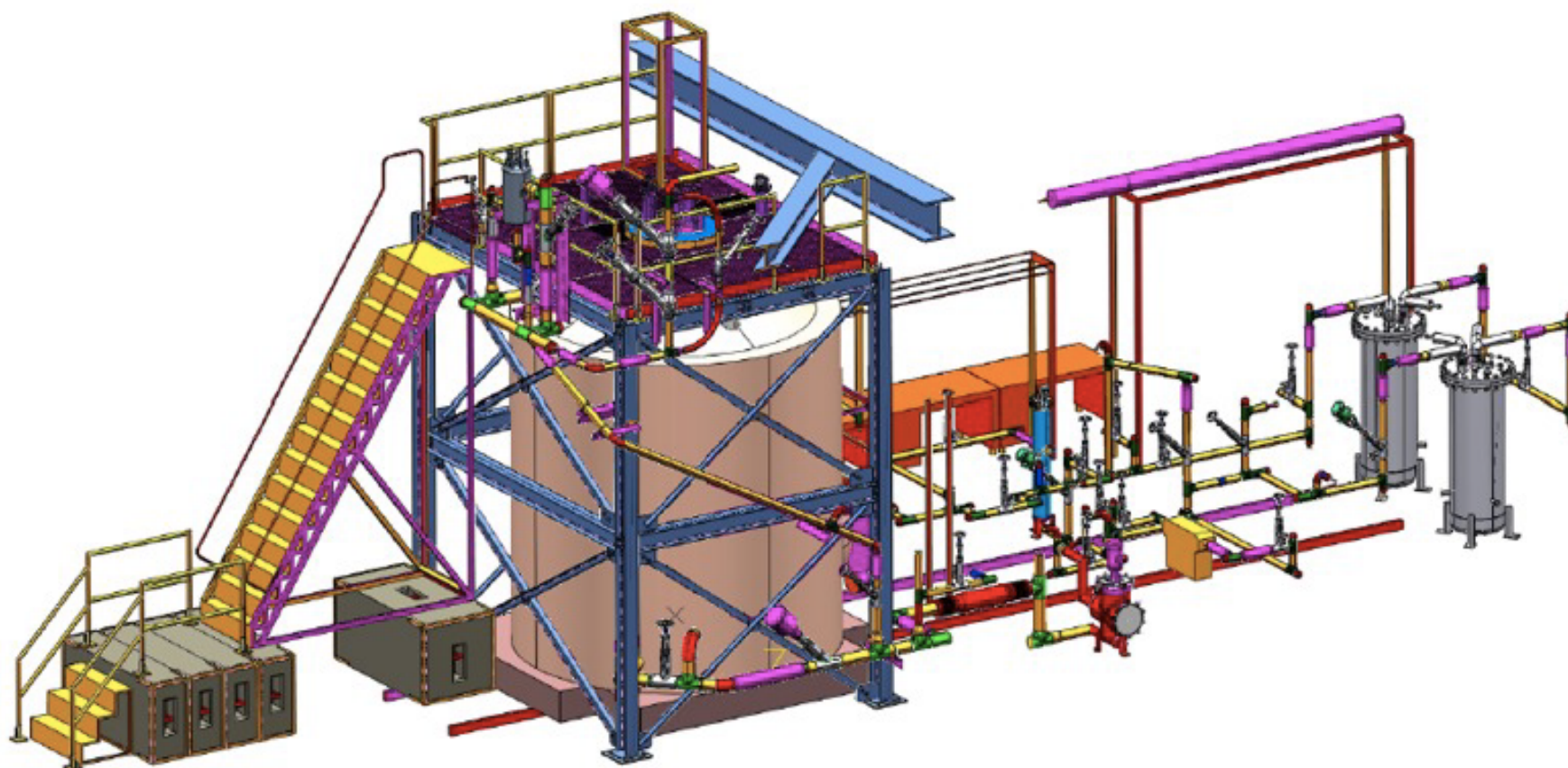


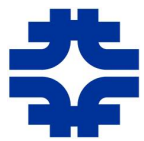


The Liquid Argon Purity Demonstrator: Status



Benton Pahlka
Fermilab





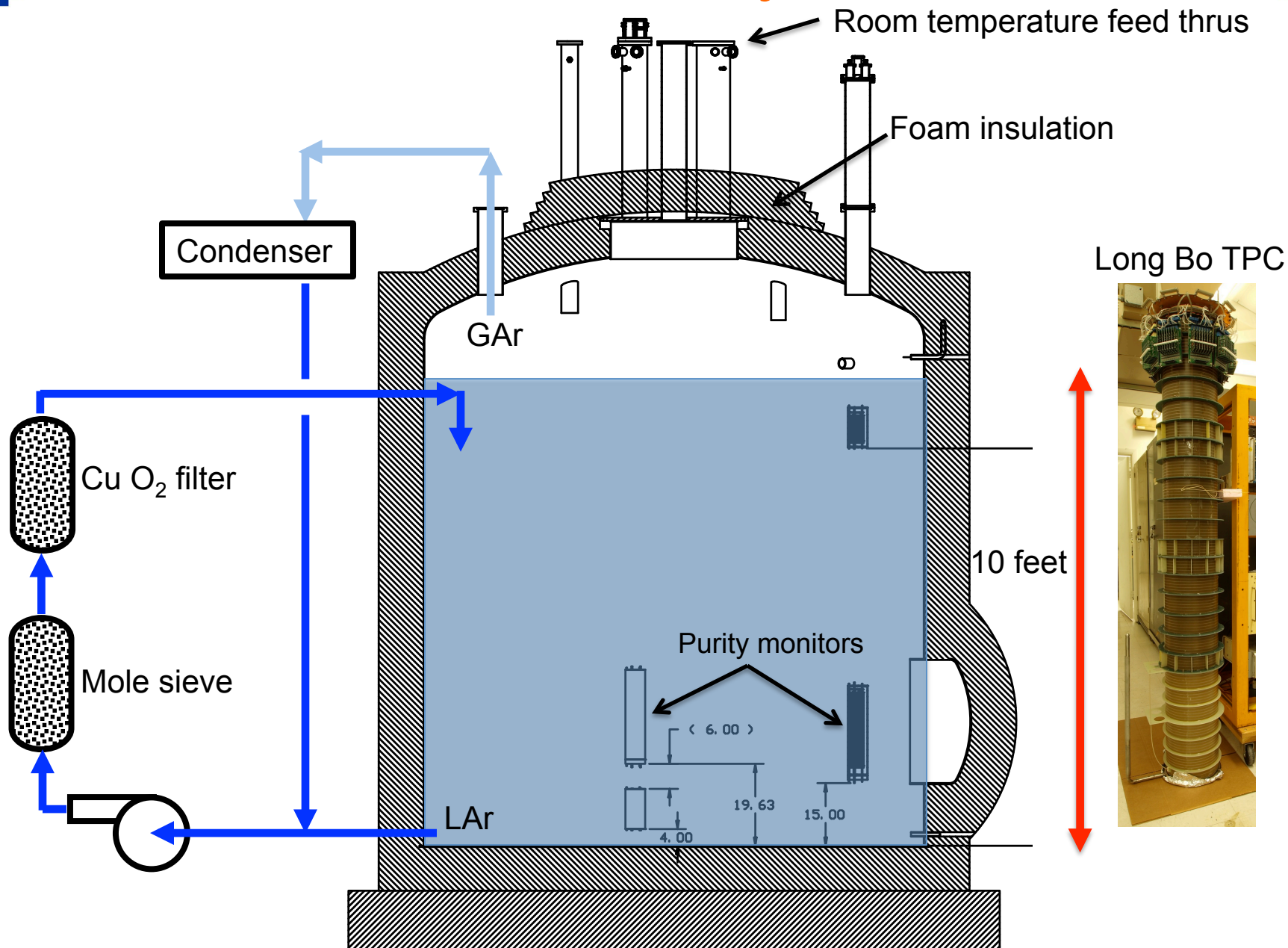
LAPD Motivation and Details



- ◆ Previous LAr systems required evacuation to achieve sufficient purity for time projection chambers
- ◆ Evacuation not practical for very large vessels
- ◆ LAPD goal is to determine if purity can be achieved without evacuation
- ◆ 30 ton liquid argon tank (5,875 gal): Cannot be evacuated
- ◆ 1st run was Winter 2011-2012
 - Achieved 3+ ms lifetime
 - Only filled 1/3 full due to commissioning caution
- ◆ 2nd run under way now (started late December)
 - Tank is “full”
 - Includes “Long Bo” TPC with 2 meter drift
 - Have again achieved and sustained 3+ ms lifetime
- ◆ Three phases of operation:
 - Argon purge
 - Gas Recirculation
 - Liquid Recirculation



The LAPD System

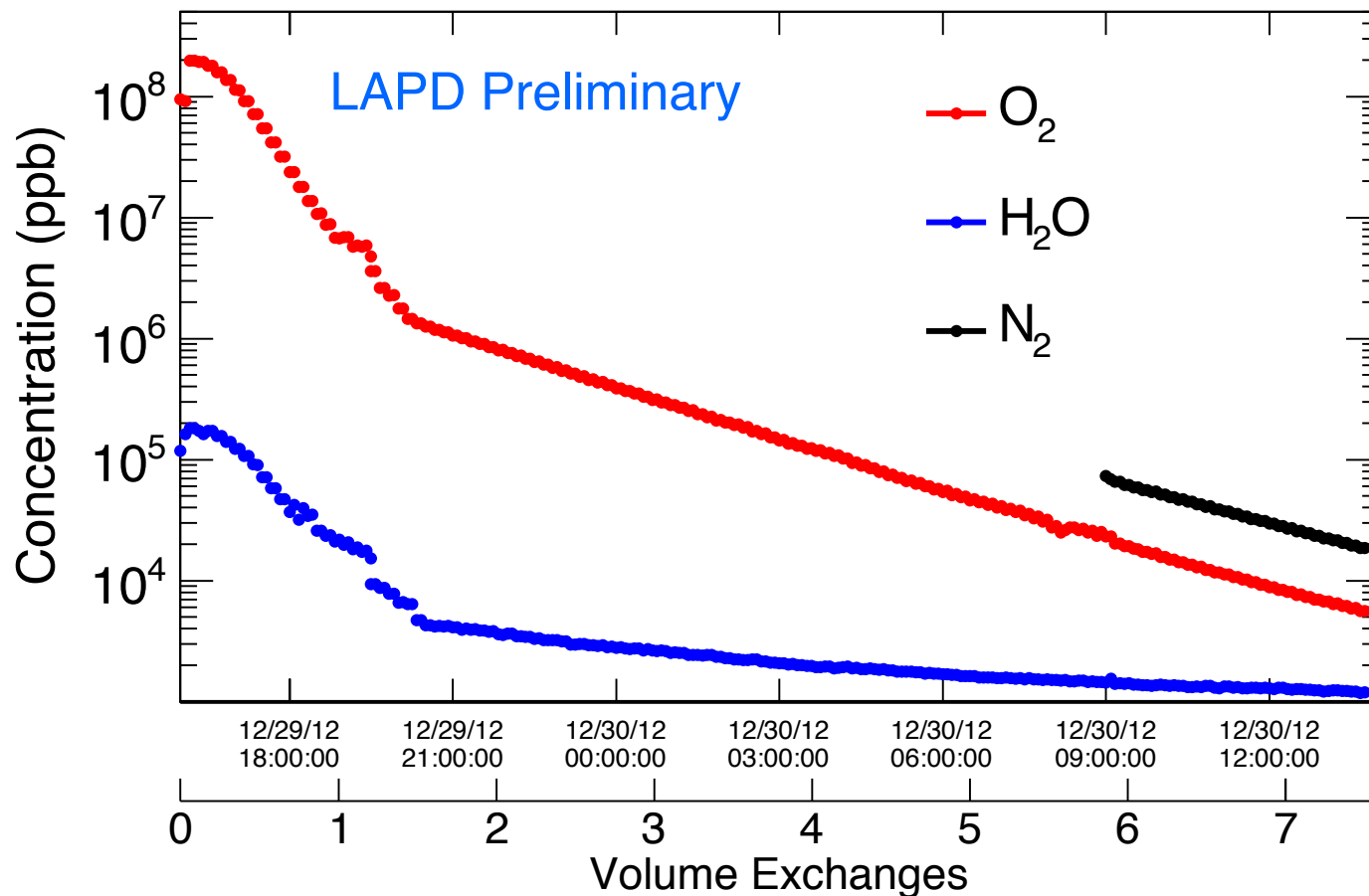
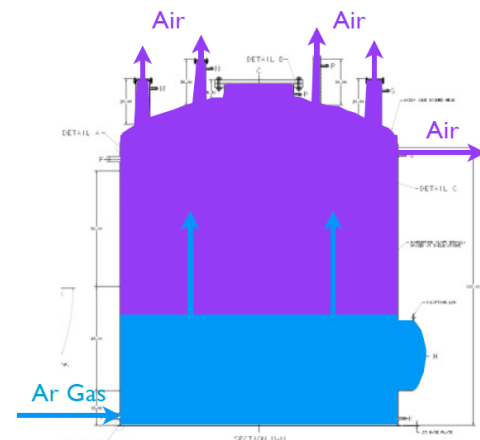




Gaseous Argon Purge Run II



- ◆ Room temperature argon gas injected into tank bottom pushes less dense air out the top at 5 ft³/min
- ◆ 3.8 ft/hr argon piston rise rate
- ◆ 2.9 hours per volume change



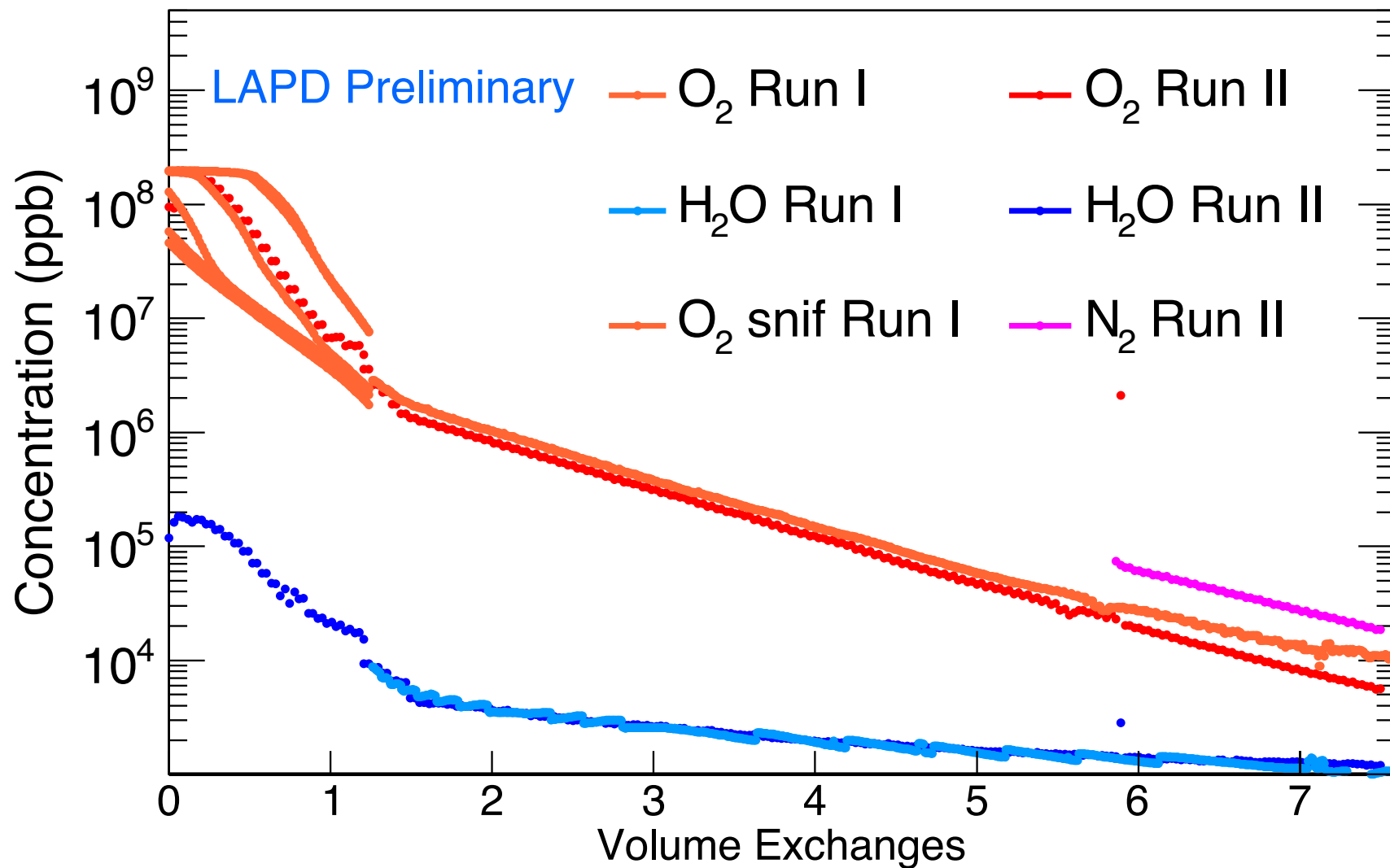
N₂ reaches
18 ppm

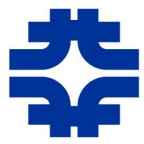
O₂ reaches
6 ppm

H₂O reaches
~1 ppm



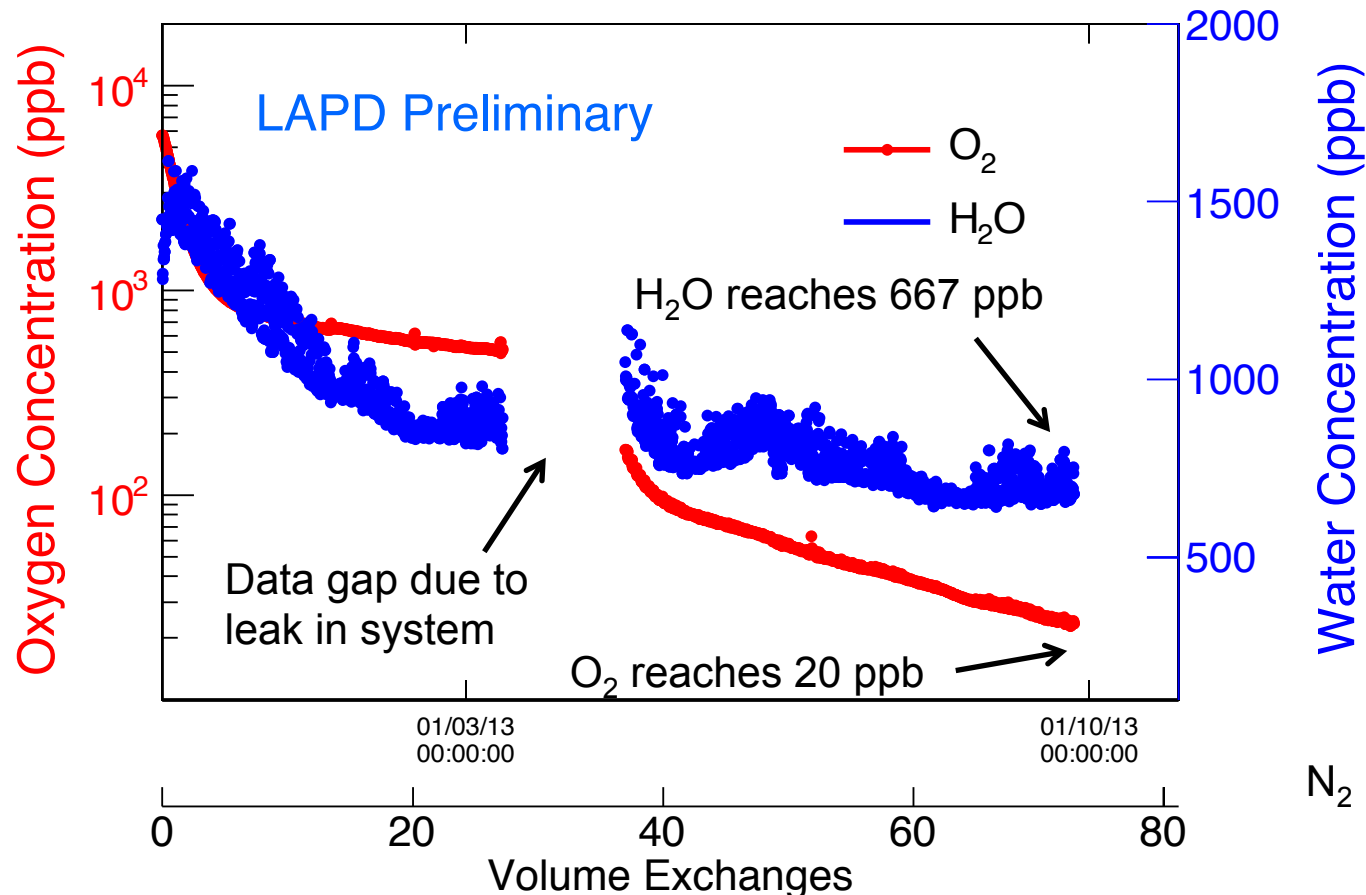
Argon Purges: Run I and II





Gas Recirculation

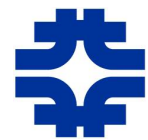
- ◆ Gas is pumped thru the mole sieve and oxygen filters at a rate of a volume change every 3.4 hours
- ◆ Gas recirculation ran for 77 volume changes (about 1 week)
- ◆ H₂O outgases “forever”: outgassing rate eventually matches filtration rate



N₂ reduced to 13 ppb



Liquid Fill



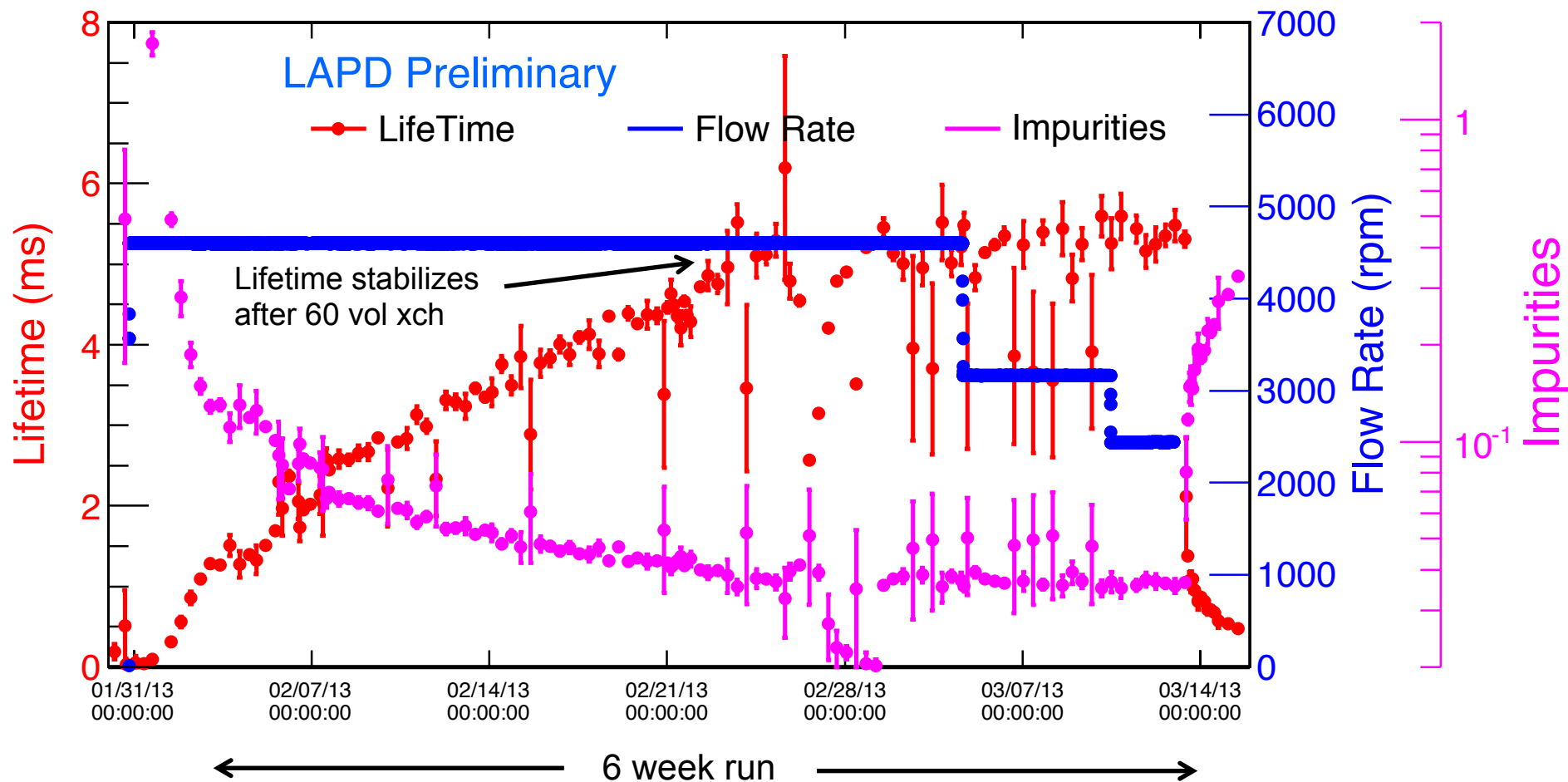
- ◆ LAPD was filled with LAr from the D0 calorimeters in 4 trailer loads
- ◆ Contamination at the start of liquid recirculation
 - Liquid phase
 - ✧ 30 ppb O₂
 - ✧ 8 PPM N₂
- ◆ Recirculation started at 2.42 vol change/day
- ◆ 1 millisecond electron lifetime achieved after 6.6 volume changes
- ◆ Stabilized at 5 ms after 60 volume changes
- ◆ Reduction of pumping speed did not reduce lifetime
- ◆ 6 weeks of successful pumped liquid purification demonstrated



Liquid Recirculation



- ◆ 30 ppb O_2 reduced to 1 ppb after three days
- ◆ Lifetime and impurities measured by purity monitors in tank (1 shown)
- ◆ Error bars are statistical (1σ): each point is average over 3 readings

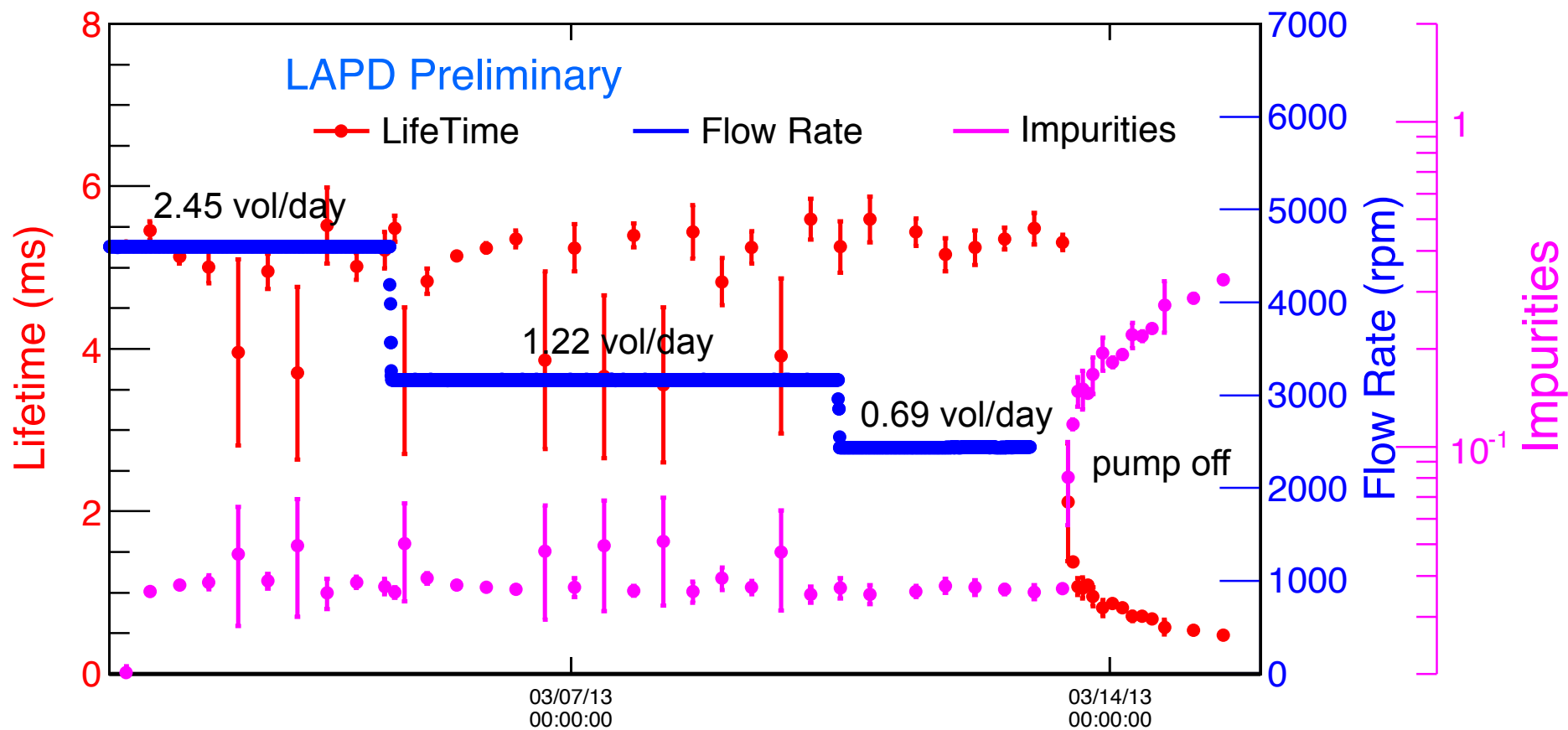




Liquid Recirculation

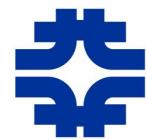


- ◆ Studied effect of variable pump flow rate
- ◆ Reduction in flow rate did not affect lifetime

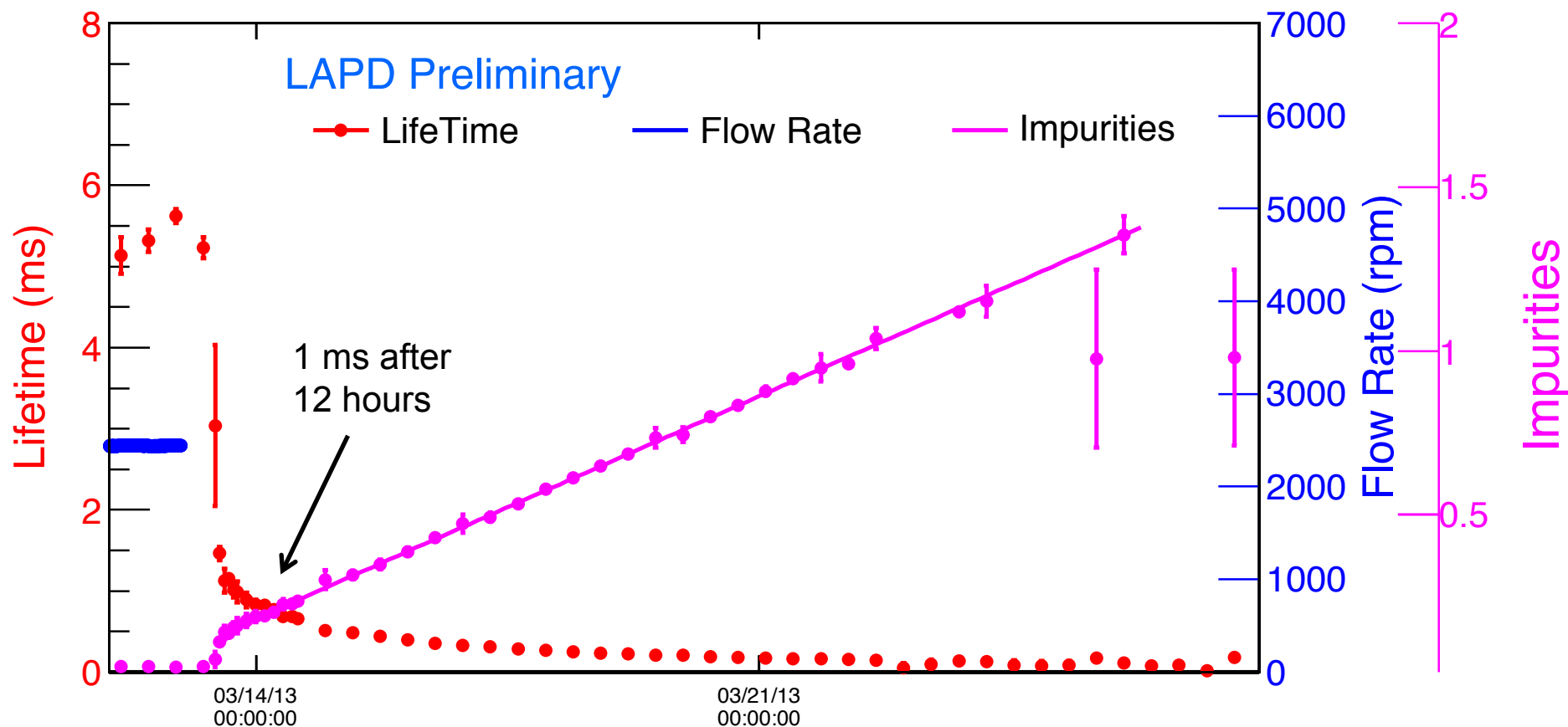




Liquid Recirculation

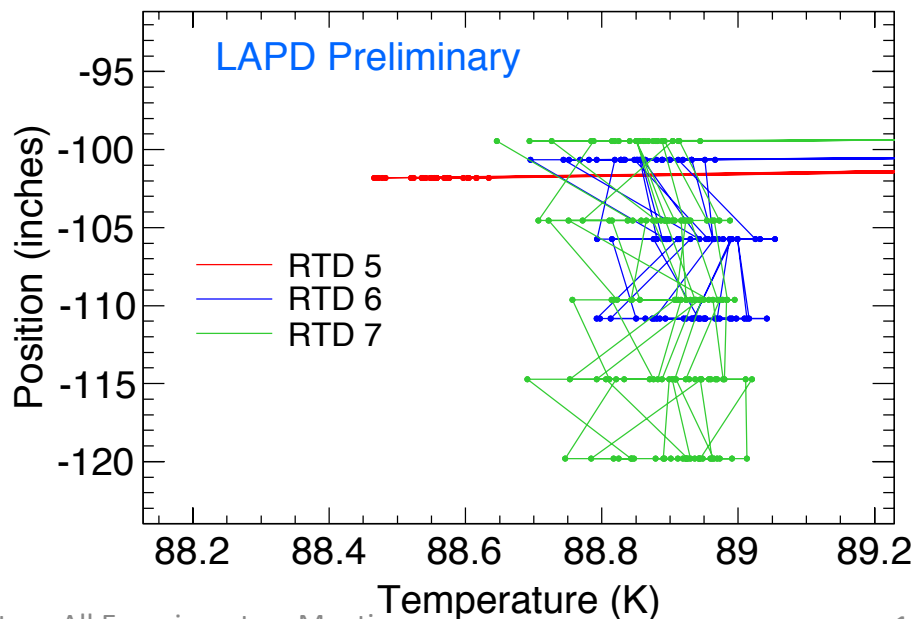
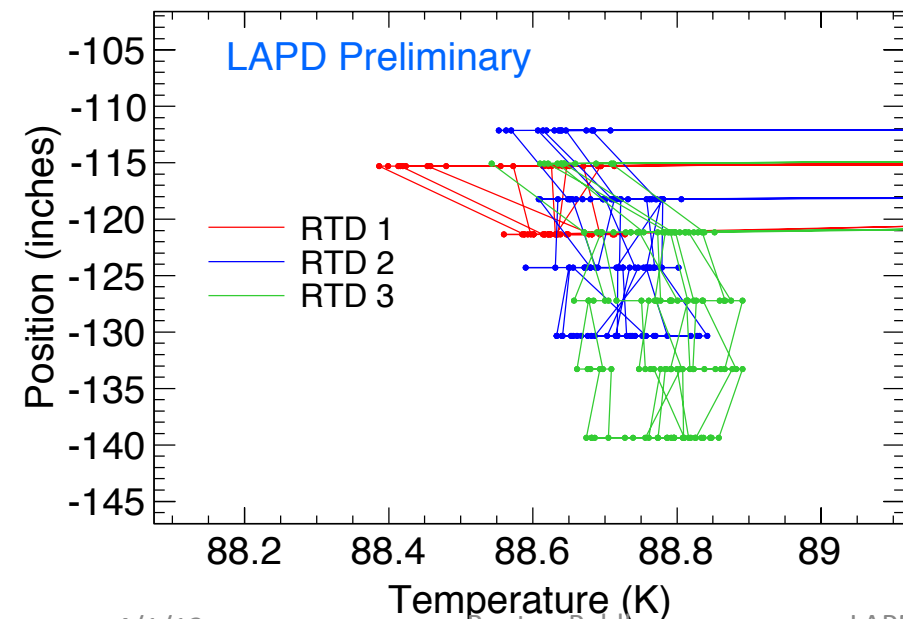
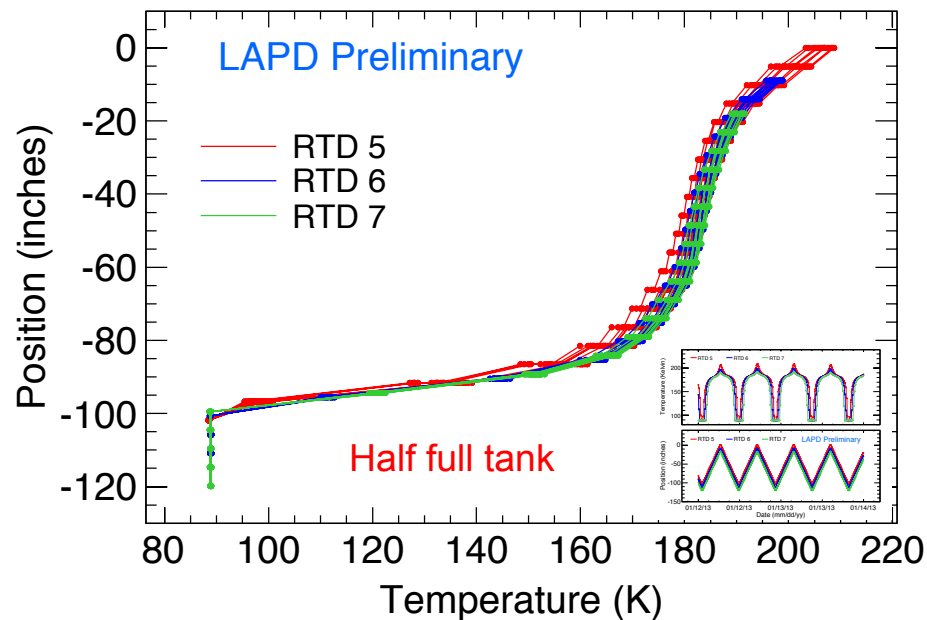
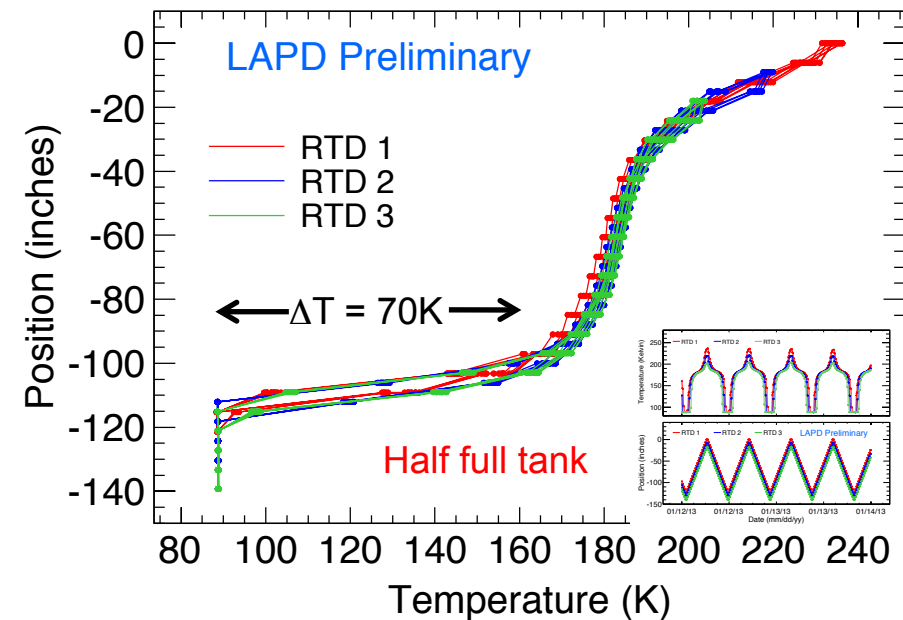


- ◆ After pump turned off, dirty condensed LAr returns to tank unfiltered
- ◆ Impurities increase linearly
- ◆ Good fit to straight line ($\chi^2 = 50/30$ for what it's worth)



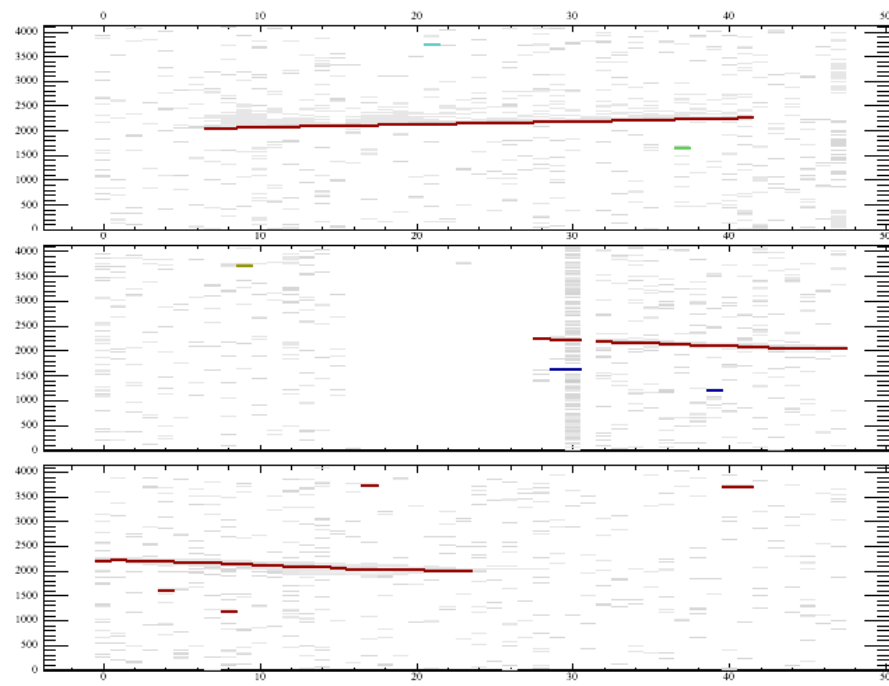
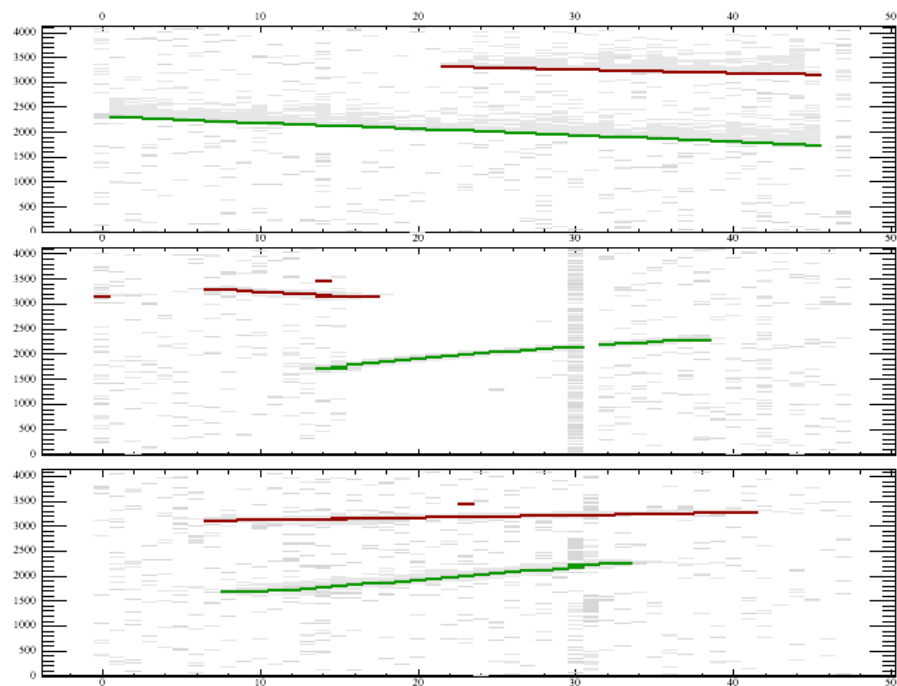


RTDs

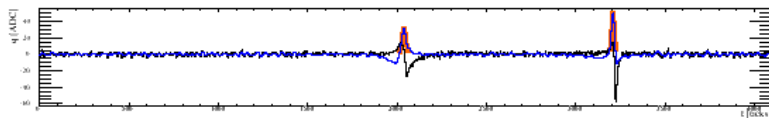




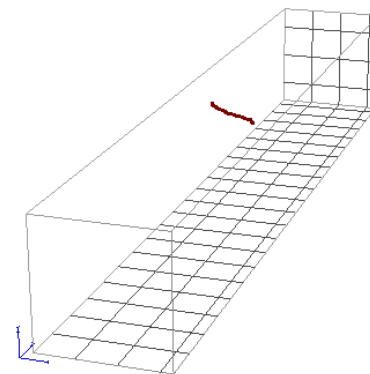
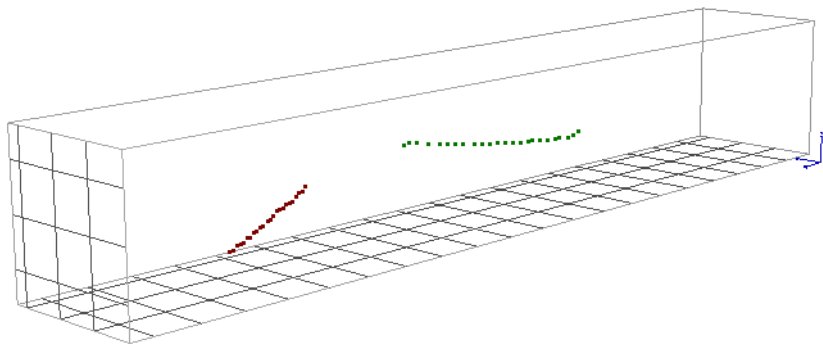
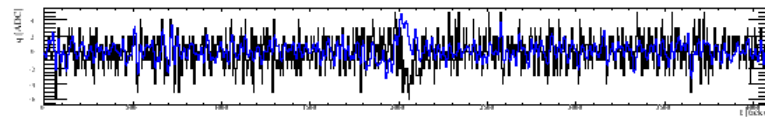
Tracks in Long Bo



LArSoft
Run: 240/1
Event: 32
UTC Fri Feb 15, 2013
18:22:51.000000000



LArSoft
Run: 240/1
Event: 5
UTC Fri Feb 15, 2013
18:21:2.000000000



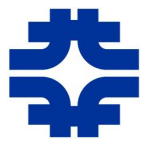


Summary

- ◆ LAPD successfully demonstrated > 5 ms lifetime in Run II
- ◆ LBNE requires 1.4 ms lifetime
- ◆ Three phase approach has aided understanding the system
- ◆ Successfully observed tracks in the Long Bo TPC

Future Work

- ◆ Data analysis of contaminants, purity monitors, other devices
- ◆ Filter capacity tests
- ◆ Injection of contaminants
- ◆ Contaminant modeling inside the tank



Thanks to People Involved

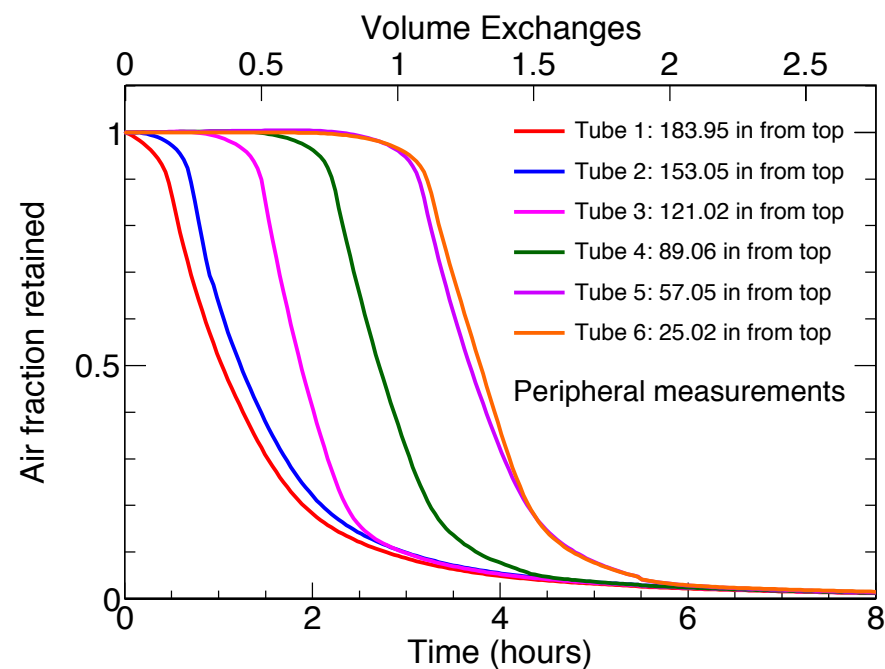
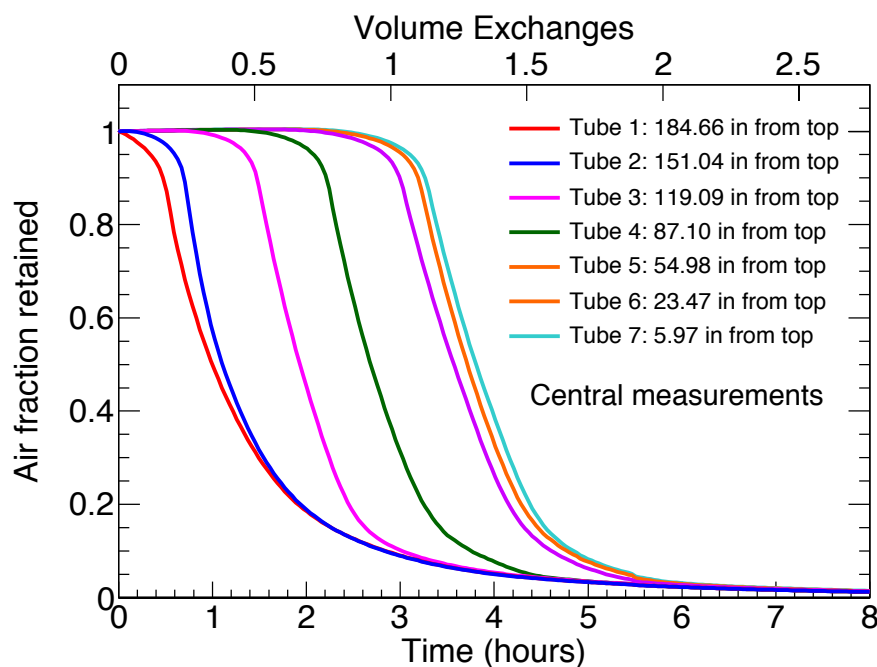
- ◆ Mark Adamowski
- ◆ Ben Carls
- ◆ Ron Davis
- ◆ Alan Hahn
- ◆ Hans Jostlein
- ◆ Walter Jaskierny
- ◆ Cary Kendziora
- ◆ Sarah Lockwitz
- ◆ Dan Markley
- ◆ Rob Plunkett
- ◆ Stephen Pordes
- ◆ Brian Rebel
- ◆ Rich Schmitt
- ◆ Eva Skupp
- ◆ Michelle Stancari
- ◆ Terry Tope
- ◆ Tingjun Yang

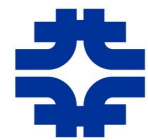


Argon Purge Run I Sniffers

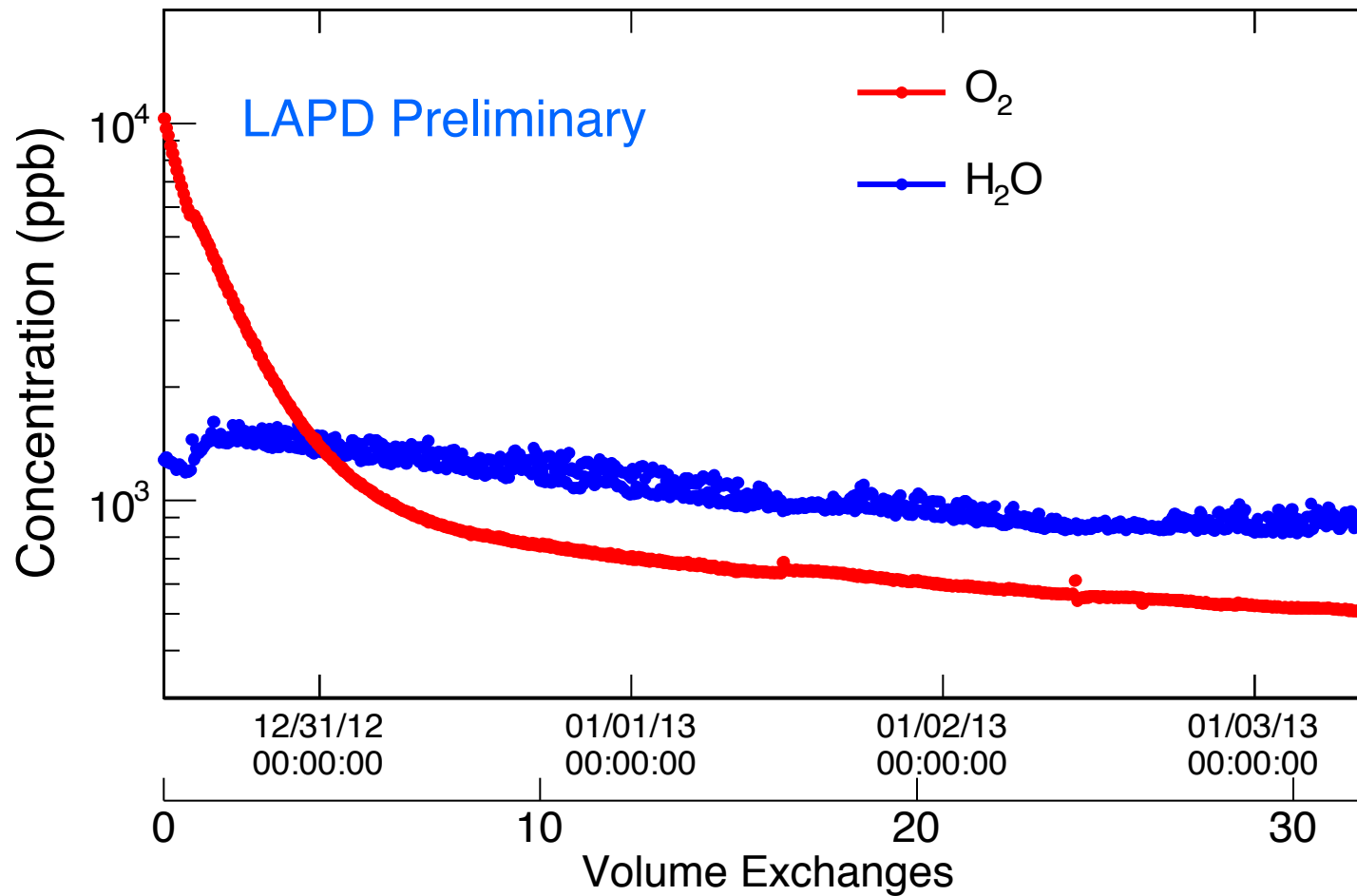


- ◆ Two sets of capillary tubes (“oxygen sniffers”) deployed at various depths in the tank during the purge measures concentration evolution
- ◆ Results shown for the argon purge for Run I





Gas Recirculation



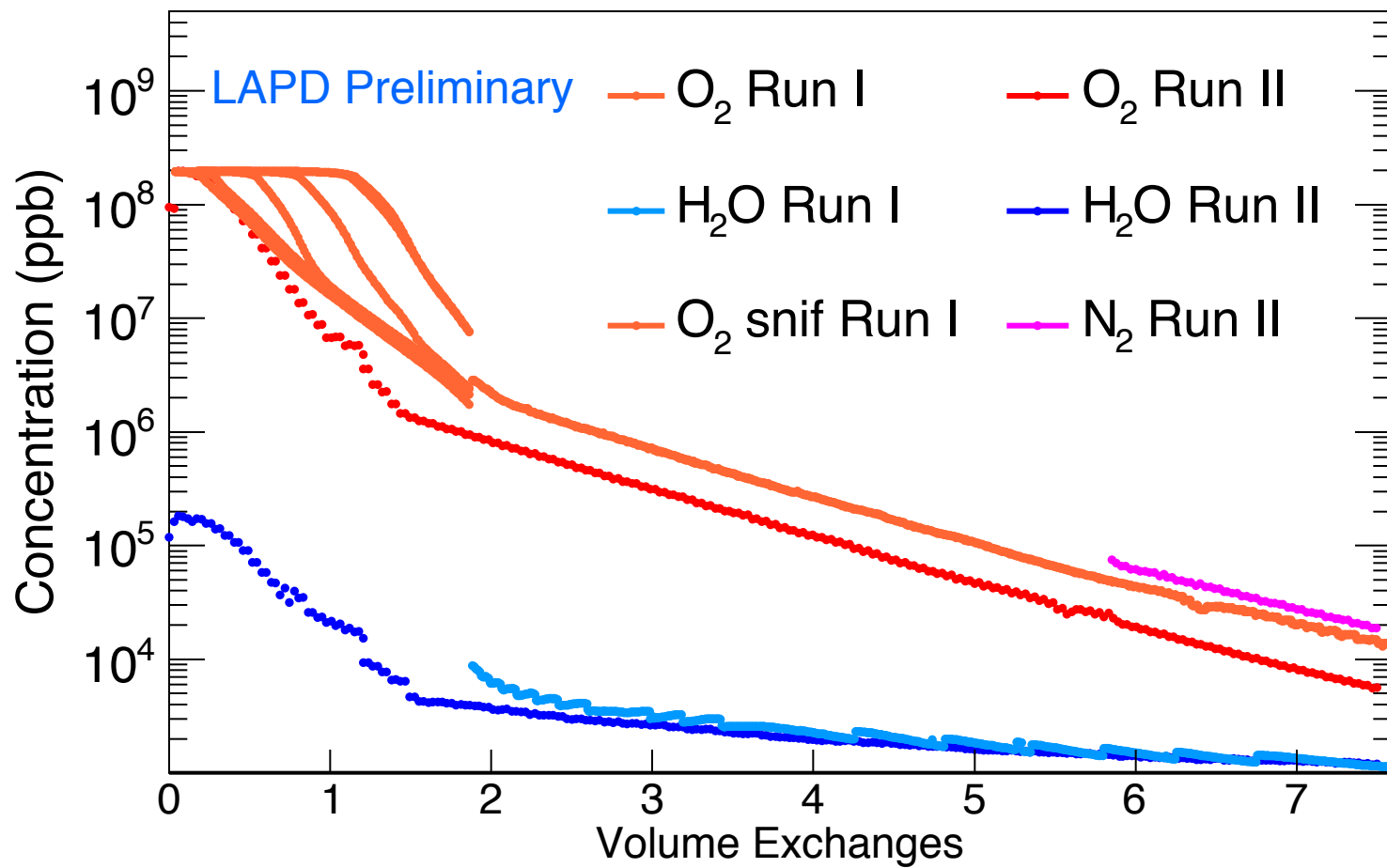
Filter Regeneration

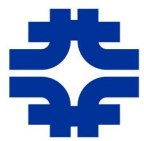
◆ Copper based oxygen filter

- External heaters warm a mix of hydrogen and argon gas to 200 C
- Hydrogen combines with oxygen to create water
- Hydrogen in Argon at levels > 2.7% is considered flammable by commercial gas suppliers
- Reaction is exothermic such that the filter self heats
- If 250 C is exceeded filter may sinter and Cu surface area and thus filter capacity is reduced
- For the 80 liter LAPD filter size 0.3% H₂ in Ar created self heating at a rate of 10 C/hr
- 2.5% H₂ in Ar led to runaway self heating
- H₂ should be slowly bled into the primary argon flow while filter temperature is monitored
- Filter is evacuated while it cools

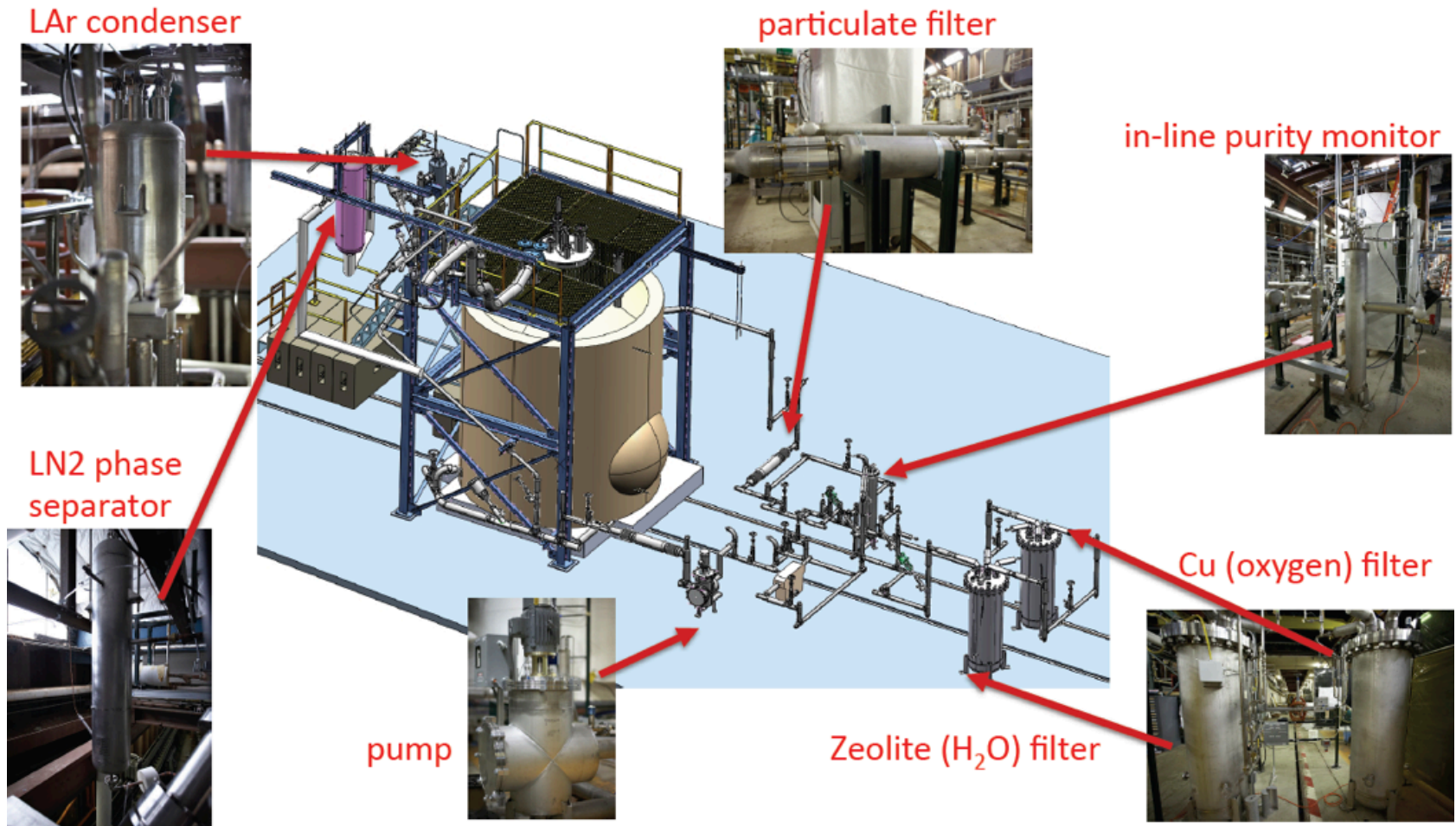


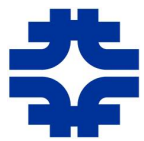
Both Argon Purges



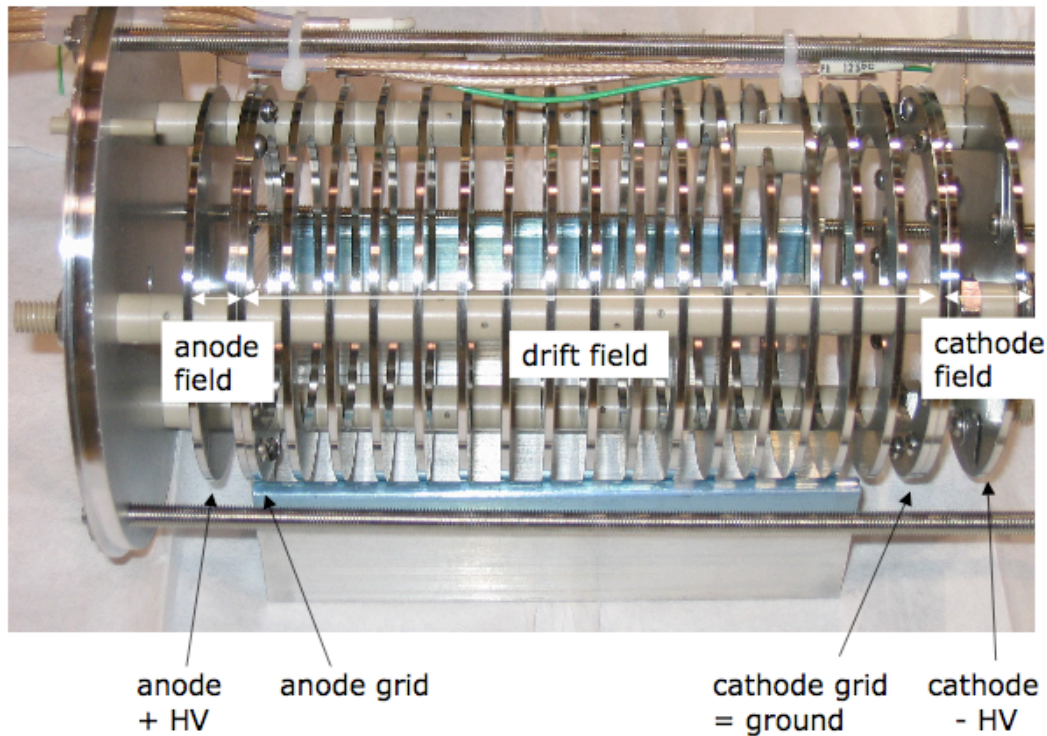


The LAPD System



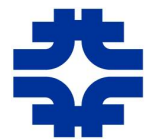


LAPD Motivation and Details





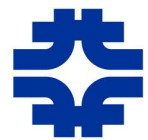
Liquid Fill



- ◆ Particulate filters to protect tank very important
- ◆ Upon entry into LAPD tank after Run 1 shocked by amount of particulate in tank
 - Not a problem for electron lifetime but may be attracted to HV surfaces
- ◆ This was despite careful pipe cleaning
- ◆ Also recommend pressurizing and then blowing down piping to blast out particulate prior to closure of piping sections
- ◆ First Run 2 fill attempt revealed a Kimwipe left in the piping – must be vigilant
- ◆ Also 1st LAr trailer load plugged fill line particulate filter



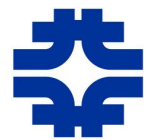
Liquid Fill



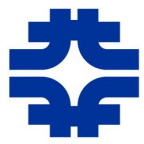
- ◆ LAPD was filled with LAr from the D0 calorimeters in 4 trailer loads
- ◆ Important to verify supply LAr contamination prior to system introduction
 - First 5,000 gallon LAr trailer supplied by commercial vendor for LAPD Run I was rejected
 - D0 LAr contamination (very good)
 - ✧ < 200 ppb O_2
 - ✧ 8 PPM N_2
 - ✧ Unable to measure H_2O in liquid – answer is always zero



Purge From Air



- How important is the purge?
- Due to the 841x mass difference between warm argon gas and liquid argon
 - 6 ppm O_2 vapor contamination adds 7 ppb O_2 to the equivalent liquid volume
 - 18 ppm N_2 vapor contamination adds 21 ppb
- Unlike O_2/N_2 , H_2O outgases “forever”
- Must purge out piping and other “dead” volumes attached to the tank that can’t be evacuated



Liquid Recirculation



LAPD Run 2 Start of Liquid Recirculation

